Troubleshooting techniques 101

By Harold Kinley, C.E.T.

Over the years the requirements of a land mobile radio technician have changed considerably. In spite of all the changes, one thing still separates the "men from the boys"—the troubleshooting ability of the technician, not age or experience. Of course, age and experience certainly tend to enhance the ability of the seasoned technician, but one must have the potential to begin.

You have probably seen "technicians" come and go who could never seem to properly diagnose problems effectively. The "hunt and miss" techniques they used just didn't cut it in the busy land mobile radio shop where turning out work on a timely basis is survival.

There is no single "right" way to troubleshoot a given piece of communication equipment. Two technicians, given the same arsenal of test equipment, may proceed differently in troubleshooting the same problem. The best method would be the one that leads to the fastest repair of the malfunctioning equipment. In this series we will look at some of the proven methods of troubleshooting that have evolved over the years, and some of the unorthodox methods as well.

The workbench

To troubleshoot efficiently, the workbench must be properly organized and equipped. The workbench should have all the test equipment that is commonly used in troubleshooting land mobile equipment. The equipment should be within easy reach from the technician's normal working position. The center piece of the equipment arsenal is the *service monitor.* The service monitor normally contains virtually all of the basic test equipment requirements in an integrated package for convenience and accessibility. Other test equipment should include a high-quality bench power supply with voltage and current metering, including adjustable foldback-current-limiting to protect both the supply and the equipment under test.

The workbench should provide sufficient space to place the service manual without taking up all the needed work space. The workbench should be kept uncluttered and should be cleaned between each service job. A cluttered workbench leads to confusion, resulting in inefficiency and, thus, longer service time. A complete set of interconnecting test cables should be nearby and kept in good repair. A bad or intermittent test cable can send the best technician on an occasional wild goose chase!

Of course, good lighting is a must. In addition, a lighted magnifier should be attached to the workbench. The age of microminiaturization necessitates this. Sometimes, a fluorescent light fixture can generate lots of noise, which may interfere with receiver sensitivity tests. Still, fluorescent lighting is desired—just make sure the lighting isn't causing noise to appear in the receiver.

Talk to the customer

The way a customer describes a problem may be confusing, and the technician should make an effort to confirm weird complaints. Remember, the customer is not familiar with technical terms and may describe a problem in an unusual manner. Quiz the customer until you gain an understanding of the problem. It may be a case of the customer not operating the equipment properly.

The equipment should be removed to the workbench only when it is determined that the problem does not lie in the installation or improper operation. Once the equipment is on the workbench, all complaints should be verified through *external* test and measurement procedures.

Confirming the symptoms

When faced with a malfunctioning piece of equipment, often the most difficult part of troubleshooting is deciding where to begin. Let the symptoms be your guide.

Suppose you are handed a transceiver, and you are told that the receiver is inoperative. That complaint is not definitive and, therefore, will require some "external" tests to provide a more definitive answer as to what type of problem exists within the receiver.

The logical step is to hook up the transceiver on the test bench and test the controls, such as squelch and volume. Also, when using the ammeter on the bench power supply, check to make sure the transceiver is drawing the proper amount of current. A large current drain in the receive standby mode would indicate a probable short circuit in the transceiver.

Run a sensitivity check on the receiver. Use both the SINAD and the 20dB-quieting method, and compare results with receiver specifications. If the sensitivity is poor with both methods, then one or more stages of the receiver apparently are malfunctioning.

If you cannot *force* a high-level signal through the receiver, it is likely that one of the local oscillators (first or second) is not working (assuming the audio section is working). Usually, unless a local oscillator is dead, you will be able to force a high-level (1,000μV or greater) signal through the receiver. It may not sound good, but you should be able to hear it in the speaker.

Operation of the local oscillator(s) can be determined through the use of a spectrum analyzer with a "sniffer" probe held near the oscillator or mixer. In synthesized receivers, the local oscillator will be a voltage-controlled oscillator (VCO). Some sets are single-conversion—there will be no second oscillator. Crystal oscillator failure is most often caused by a defective crystal. In synthesized sets, if the synthesizer is "out of lock," the entire transceiver usually is disabled by the *lock detector.* An *out-of-lock* condition can be caused by a variety of problems within the synthesizer—missing reference oscillator, missing VCO signal, alignment problems, programmable divider problems and a host of other ills.

To find the defective component(s), troubleshooting must follow some *systematic* procedure. Generally speaking, the trouble must be localized to a *section.* Once the defective section is determined, the trouble is next localized to a *stage.* Then within the stage, the trouble must be localized to the defective *component(s).* Again, the method used to implement this process may vary from technician to technician; however, there are some general rules that can apply.

Next time we will examine several techniques for signal tracing and signal injection that are used to troubleshoot typical land mobile radio communications gear. We will look at some short cuts that can lead you to a dead or seriously impaired stage quickly.

So, until next time—*stay tuned!*

Kinley, a certified electronics technician, is regional communications manager, South Carolina Forestry Commission, Spartanburg, SC. He is a member of the Radio Club of America. He is the author of *Standard Radio Communications Manual: With Instrumentation and Testing Techniques,* which is available for direct purchase. Write to 204 Tanglewylde Drive, Spartanburg, SC 29301.

Troubleshooting 101: Part II

By Harold Kinley, C.E.T.

Troubleshooting is the science (or art?) of finding the defective section, stage and component of a malfunctioning piece of equipment in the shortest possible time. Almost anyone can replace a defective component, but finding the culprit in a complex circuit is what separates the men from the boys in the shop!

Many years ago, I was doing come CB repair work on a moonlighting basis. A gentleman brought in a CB transceiver, and although I was busy at the time, he convinced me to drop what I was doing to work on his defective transceiver. After about 30 minutes of troubleshooting work, I found the culprit to be a leaky capacitor. After I showed the customer the problem, he asked how much the repair would cost. After I informed him that the repair charge would be $20, he advised me to "button up" the radio and not to repair it.

So, I "buttoned up" the radio and charged the gentleman(?) $15 for the troubleshooting time. I knew he would simply buy a replacement capacitor and replace it himself after I had identified the defective component for him. He had some ability with a soldering iron but not much at troubleshooting. Again, anyone can *replace* a component, but it takes a real troubleshooter to *find* the defective component(s).

This month we will look at a couple of troubleshooting techniques that, although a little unorthodox, are quite useful.

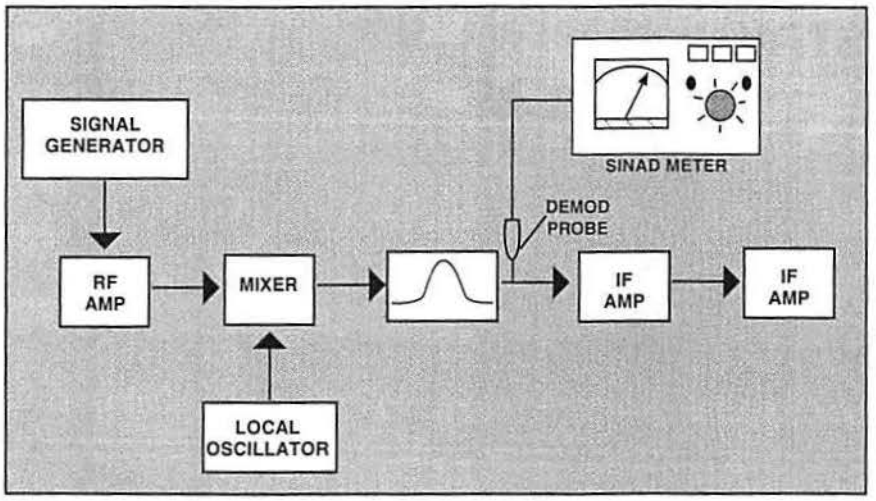

Figure 1. To use a SINAD meter as a signal tracer, just hook the demod probe to the SINAD meter input.

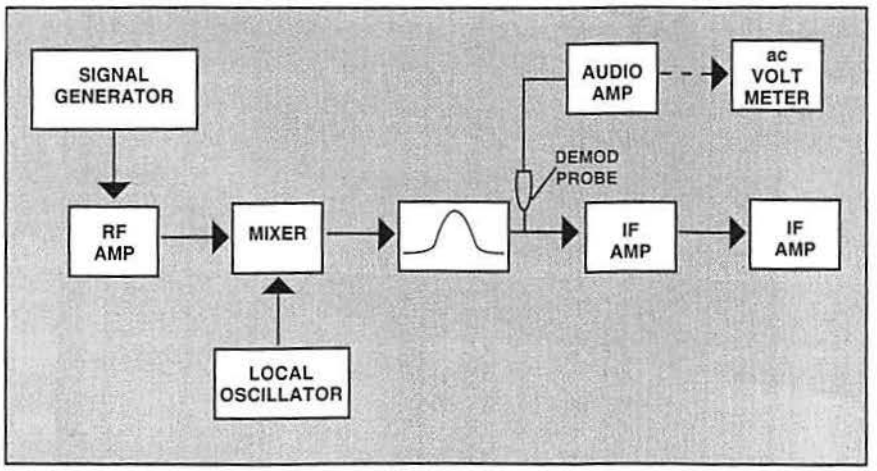

Figure 2. An audio amplifier, such as the Radio Shack model 277-1008, can be used as a signal tracer with a demod probe as shown. An ac voltmeter can be plugged into the phone jack to get a voltage reading as a reference.

Signal tracing

Suppose you are troubleshooting a receiver that has a weak (low gain) or dead stage. You can force a high-level signal through the receiver, but the sensitivity is poor. First, the defective stage must be located.

In AM receivers, a simple demodulator (demod) probe can be used in conjunction with an audio amplifier to trace the AM signal through the receiver. Aside from the limiter stages and detector, the FM receiver is no different from the AM receiver. This means that a simple demodulator probe can be used to trace the signal in the FM receiver.

Besides the demodulator probe, an audio amplifier with optional metering is needed. The audio amplifier simply amplifies the *demod* probe output and allows it to be heard in the loudspeaker. To use this method, simply apply a high-level signal to the input of the receiver. The signal must be *amplitude-modulated* at a high level (about 70% to 80%) using a 1kHz tone. By moving the demod probe from input to output of the various stages, the malfunctioning stage can be located. Relative stage gain is indicated by changes in the tone level from input to output.

If you happen to have a SINAD meter with a built-in audio amplifier and a voltage scale with decibel calibrations, so much the better. The demod probe can be connected to the input of the SINAD meter, and the voltmeter can be used as a better indication of stage gain, while the speaker serves as aural indication (if you are simply signal-tracing and not interested in stage-gain measurements).

It is important to keep the input signal level as low as possible to prevent overloading the audio amplifier or the SINAD meter. The preferred method is to set the RF signal input level just high enough to produce a usable reading at the SINAD meter-audio amplifier with the demod

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two capacitors and a diode connected between the voltage rail and ground. One of the components is shorted, but which one? Each component could be disconnected one at a time to observe the effect on current drain, but suppose they are very difficult to gain access to—what then?

Since printed circuit foils possess a certain amount of resistance (depending on thickness, width and length) a small amount of voltage drop will appear across the foil when current flows through it. That is the basis for the following procedure.

A digital voltmeter is connected across the ends of the voltage rail as shown in Figure 3B on page 50. Then a battery is connected, as shown, with a 2Ω resistor connected in series. The resistor serves to limit current flow through the circuit foil in order to protect the foil from overheating and burning. At the same time, enough current is allowed to flow so that a measurable voltage drop is produced. At Figure 3B, let's suppose that capacitor C1 is shorted. With the resistor connected at the point shown, the dc voltmeter will indicate a *negative* reading. That means the probe has been placed on the negative side of the short as referenced to the voltmeter terminals.

If the probe is moved farther to the right as shown in Figure 3C on page 50, then the voltmeter will indicate a more negative value, indicating that the probe is father removed from the short circuit in the direction of the negative voltmeter terminal.

If the probe is repositioned as shown in Figure 3D on page 50, then the voltmeter will indicate a *positive* reading, meaning that the probe has been placed on the positive side of the short as referenced to the voltmeter terminals. If the probe is moved farther to the left (Figure 3E on page 50), then the voltmeter will indicate a more positive value, indicating that the probe is farther removed from the short circuit in the direction of the positive voltmeter terminal.

To locate the short circuit, the probe is moved along the rail until the voltmeter reads "000." This is the pinpoint location of the short circuit, and the component connected to this point is the culprit.

Instead of using the battery with the current-limiting resistor, a constant-current power supply could have been used. Be sure to limit the current to the minimum amount that provides a usable reading on the voltmeter. In some cases, the current may have to be increased to produce a sufficient voltage drop for this method to work. Just be sure to limit the amount of time the probe is connected to prevent burning the circuit trace.

Another useful tool for locating short circuits is the "Shortsqueek" from Global Specialties. It emits an audible tone, and as the probe is moved closer to the location of the short circuit, the tone increases in frequency. By listening to the tone frequency you can locate the source of the short circuit.

Whether you are troubleshooting down to the component or to the board, don't be afraid to try new troubleshooting techniques. Some techniques are more efficient than others, so try to use the technique and equipment that fits the situation. Learn to adapt.

Next time, we will conclude this miniseries on troubleshooting.

So, until next time—*stay tuned*!

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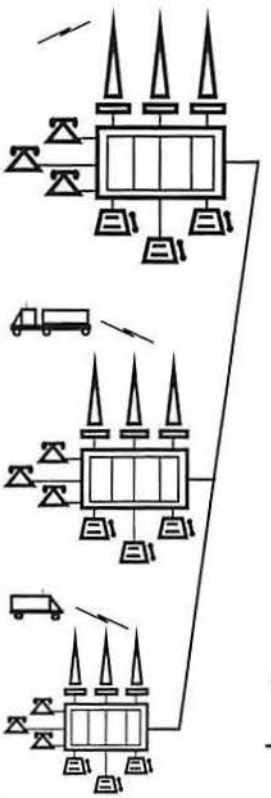

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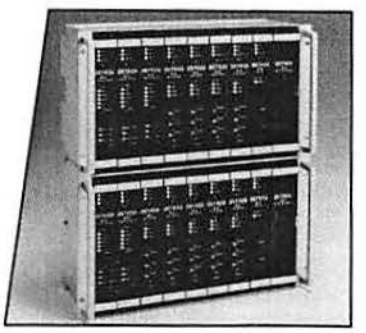

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Troubleshooting 101: Part III

By Harold Kinley, C.E.T.

The ability to troubleshoot electronic circuitry effectively and efficiently is composed of three things: knowledge, experience and an innate ability. The reference to an *innate* ability may sound unscientific and even ludicrous, but ask the old veteran service-shop managers who have "been through" many technicians over the years, and they will tell you that there is something besides knowledge and experience that goes into making the expert troubleshooter. It is intangible, but it marks the true troubleshooter!

Notice that I haven't mentioned test equipment? Test equipment is essential to troubleshooting complex electronic equipment, but it does not a troubleshooter make. Give your worst troubleshooter the best equipment and your best troubleshooter the worst equipment, and who do you think will get the job done? This is not to say that good test equipment is not necessary for good troubleshooters. It has to do with efficiency and doing the best possible job. Good test equipment in the hands of a good troubleshooter will yield the best possible results in the shortest possible time.

Resources

When troubleshooting a piece of equipment, use all the resources that may be at your disposal. This is not limited to test equipment. Don't overlook technical acquaintances or associate technicians who might have successfully dealt with the same problem in the past. Human resources are usually the best resources.

If you have another piece of equipment identical to the equipment you are troubleshooting, use it as a reference in analyzing test and measurement procedures you are performing on the ailing equipment. This expedites repairs and avoids a wild goose chase!

Keep notes on unusual problems and their solutions for future reference. Share them with your fellow technicians. Not only will they think you are a swell person, they might even buy your lunch! As we get older, the notes are even more important. Ever run across a strange problem and get a feeling of déjà vu? Yep—been there—done that—just can't remember the solution, only the problem! Now, you have to reinvent the wheel. If *only* you had made a note—or kept the note you did make where you could find it! Oh well, "next time," will you say?

Other resources are the troubleshooting flow charts that are commonly found in service manuals. These insult your intelligence, you say? Well, I used to think the same way until I really put one of these charts to the test on an occasion. Some of these charts really work, given the chance. Granted, some are much better than others. An example of a *bad* flow chart is shown in Figure 1 above. This is a deliberate exaggeration, but not too far from some I have seen!

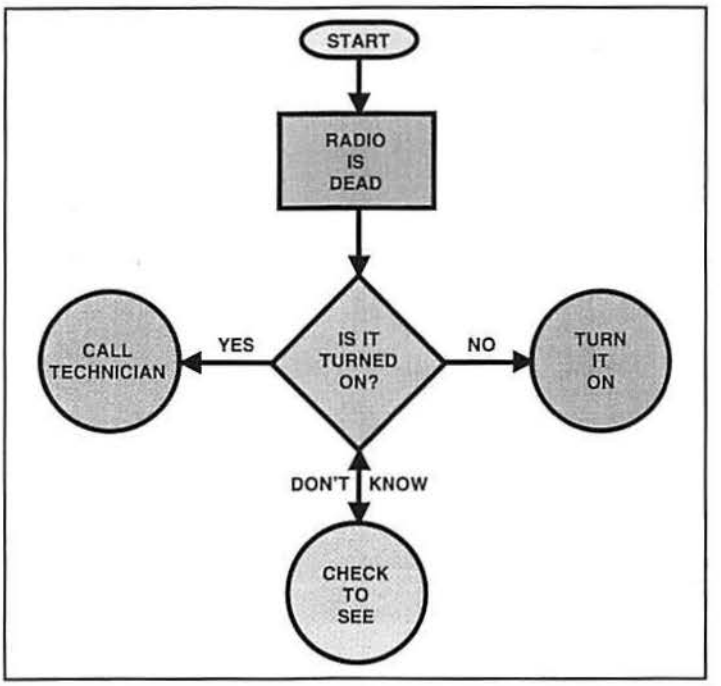

Figure 1. Some service manual troubleshooting flow charts like this one may seem to insult your intelligence, but good charts can be a valuable resource.

When all else fails, *study the manual!* You may have to do some in-depth reading and hard concentration. The solution to your problem may not appear in the manual in so many words, but often something in the text will trigger a thought process that leads you right to the trouble. Studying the manual includes studying the schematic diagram as well as the functional block diagram. In complex equipment, the functional block diagram is often the best place to start. This gives you a quick and logical overview of how all the individual circuit boards or subsystems are integrated to form the complete system.

More troubleshooting techniques

There are many different troubleshooting techniques. Basically, they can be reduced to a few when generalized as *voltage-resistance-current measurements, waveform checks, signal injection* or *signal tracing.* Actually, signal tracing and signal injection are about the same—one is simply the complement of the other.

Technically speaking, signal injection and signal tracing must be used together, since there must be a signal injected somewhere to be traced, and vice versa.

When testing mobile radio receivers on the bench, be sure to check the operation of the transceiver over a voltage range of 11V–15V. Even higher (or lower) voltages may occur in mobile installations, but the transceiver cannot be expected to operate properly at extremely high ends of the voltage range. Certain problems in particular transceiver models tend to show up on a predictable basis at high or low supply voltages.

One case history in particular comes to mind. A firefighter complained that his transceiver (installed in a diesel crawler tractor) started "howling " while in use on a fire suppression incident.

To gain more insight into the nature of the trouble, I carefully quizzed the firefighter. I learned that the volume control setting had no effect on the "howling," which would begin after the tractor

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Technically speaking

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got "warmed up" and would only cease when the tractor was throttled down and the radio was turned off and then back on.

I had the firefighter bring the tractor into the installation bay next to the radio shop so that I could begin troubleshooting with the radio still installed in the tractor.

With the tractor not running, I turned the radio on and found it to be operating normally. Then I started the tractor and let the engine run at low throttle for several minutes—still no evidence of trouble from the radio. Then I increased the throttle until it reached a point where the radio started "howling." Yes, indeed, I *do* mean "howling!"

As the firefighter had stated, the volume control had no effect on the howling. Next, I throttled down the tractor engine—but the howling persisted. I turned the radio off and back on, and the howling was gone. Now, what was the cause?

The next step was to connect a dc voltmeter across the battery and repeat the previous process. The initial battery voltage was around 13V, but when the engine was started and throttled up, the battery voltage started climbing. When the battery voltage reached the 16V threshold, the radio would start howling. Aha! The voltage regulator! The regulator was replaced and that took care of the problem.

Since then, I have encountered the same problem many times, and the voltage regulator has always been the culprit.

Again, check mobile equipment over a range of supply voltages in verifying complaints or in troubleshooting a problem.

In modern transceiver circuits, you will usually find several different supply voltages from the power supply or power distribution board. The digital circuitry generally operates from a 5V supply point. There may be other supply voltages as well (including the full battery voltage for mobile transceivers).

For base stations, the rule is the same—check all supply voltages. It is also a good practice to scope the supply voltage points to determine if the supply voltage is clean. The ripple component should be very low and free of spikes. Also, for regulated supply points, check to make sure the voltage regulation is within bounds.

Don't overlook using the spectrum analyzer as a signal-tracing tool when troubleshooting receivers and exciters. Watch the maximum input level to avoid damaging the front end of the spectrum analyzer. If the input impedance of the spectrum analyzer is 50Ω, then you can expect it to cause serious loading of the circuit under test. However, you can use a simple and inexpensive low-capacitance scope probe (10/1) to reduce the loading effects. Any attenuation caused can be reduced by the use of a preamplifier between the scope probe and the analyzer input.

This procedure works particularly well if you use a known good transceiver to establish reference measurement levels ahead of time using the same test equipment, including probes and preamplifier. This establishes a good benchmark for future reference and is particularly valuable if you service many transceivers of the same model. There are manifold returns on the time used in making such measurements.

Many manufacturers' spectrum analyzers also offer a special preamplified, high-impedance, signal-tracing probe that allows the analyzer to be used for signal tracing in circuits with minimal loading effects. Such probes are called *active* probes. The probe supply voltage usually comes directly from the spectrum analyzer.

Conclusion

The best advice in troubleshooting is to *keep an open mind.* Let your troubleshooting tests and measurements lead you to the problem. Don't guess what you think the problem may be and then set out with test procedures to prove that you are right.

No test procedure is useless. Even though it may be way off base, it will provide you with some information. However, each test procedure should lead you one step closer to the problem part or board. Don't rule out any component based on appearance alone. No matter how innocuous it may look, it *can* be bad! Electronic components often look like new on the outside, but are totally "zapped" on the inside!

Make sure you thoroughly understand the circuit you are troubleshooting. Without an understanding of how the circuit *works*, you will not be able to understand what makes it *not* work.

Know and understand the limitations of your equipment and the situations where false readings can occur. Know when to get a second opinion by another method.

Keep your test equipment properly maintained and calibrated. Keep fresh cells in battery-operated equipment and have spare batteries on hand. Keep your test leads and probes in good condition.

By following some of the basics set forth in this series, along with hard work, you can become a better troubleshooter. By successfully meeting the challenge of each troubleshooting job, you gain experience, knowledge and confidence that will allow you to successfully meet greater challenges.

Until next time... *stay tuned!*